Third United Nations International Conference on the Peaceful Uses of Atomic Energy

A/CONF.28/A/477
GERMANY, FEDERAL REPUBLIC OF
February 1964
Original: ENGLISH

Confidential until official release during Conference

Abstract

PROPERTIES AND TECHNOLOGY OF ZIRCONIUM ALLOYS WITH NIOBIUM AND TIN

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Since some years zirconium alloys with niobium have been of interest in respect of their use as cladding and structural materials for water-cooled nuclear reactors. Three research contracts of the European Atomic Energy Commission (EURATOM) with Metallgesellschaft AG dealt with factors influencing the behaviour of zirconium alloys with niobium and tin.

The corrosion resistance of many zirconium alloys containing up to 5% niobium and up to 1.5% tin with additions of palladium, chromium and molybdenum was investigated by exposing the specimens to 350°C water and 400 and 480°C steam. It was found that the heat treatment has a great influence on the corrosion behaviour. With an appropriate heat treatment the zirconium niobium alloys have nearly the same corrosion resistance as zircaloy-2. The best corrosion resistance was attained by annealing below the α/β-transformation range which was investigated by constitutional studies at 580°C $\pm$ 10°C. With the appropriate heat treatment the corrosion resistance is nearly independent of the niobium content. Annealing above 600°C causes the appearance of β_{Zr} which has an unfavourable effect on the corrosion behaviour. Tin additions have a favourable effect at 350°C, no effect at 400°C and an unfavourable effect at 480°C.

The hydrogen pick-up of niobium containing zirconium alloys during corrosion is less than it is found in zircaloy-2.

Due to their hot strength alloys with more than 2% niobium are superior to zircaloy-2. Especially an alloy with 3% niobium and 1% tin showed excellent corrosion resistance and hot strength. The tin content is necessary to have a good strength at temperatures up to 450°C. This alloy was studied more intensively.

A hydrogen content in the alloy ZrNb3Sn1 favours a martensitic structure with an increase of hardness. A hydrogen content up to 1000 ppm has no bad influence on the creep strength. Impact tests showed that hydrogen-containing and hydrogen-free samples of ZrNb3Sn1 are superior to the corresponding samples of zircaloy-2.

It is possible to fabricate seamless tubes of ZrNb3Sn1. The fabrication possibilities are discussed. The alloy may be welded by normal welding procedures, used for zirconium, but it is necessary to heat treat the welds to improve their corrosion resistance.

The influence of a neutron radiation on the properties of ZrNb3Sn1 was tested in the Geesthacht reactor FRG 1 of the Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt mbH. Samples for testing the radiation effect on the tensile and impact properties and on the structure were kept in the coolant of the reactor. Corrosion tests under irradiation were performed in heatable autoclaves within the reactor. The maximum radiation dose was $8 \cdot 10^{19}$ nvt. The results of the radiation tests are discussed.